Passive source location by diffraction scanning

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Calgary, December 3 2021

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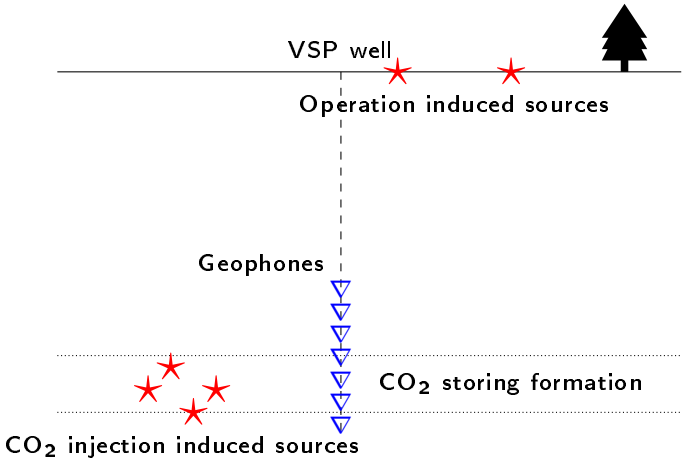
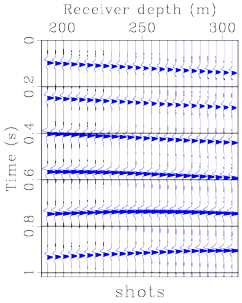
Introduction

Passive seismology during CO_2 storing



Delay and sum techniques



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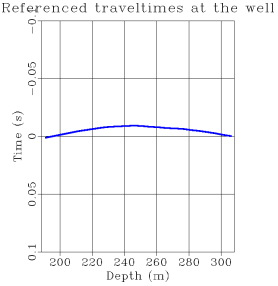

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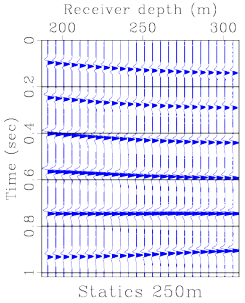
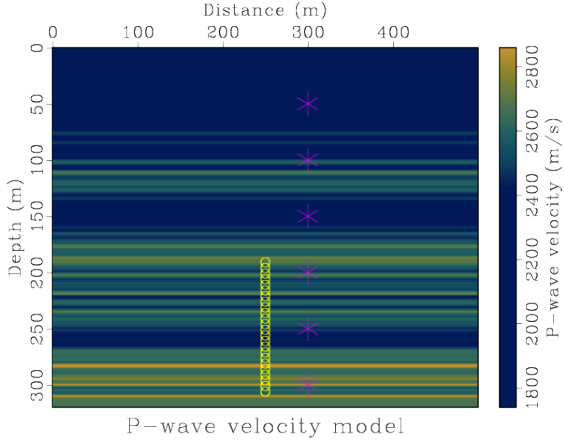
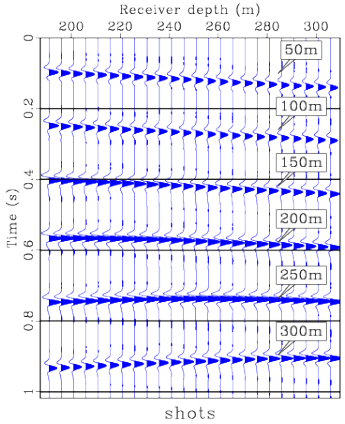


Measure the lateral coherence.

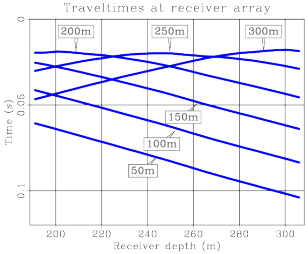
Methods

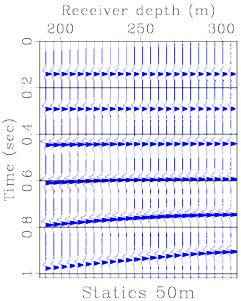
Passive sources configuration

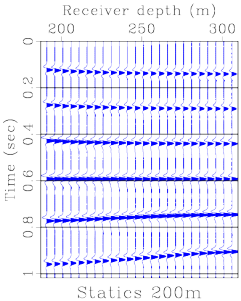


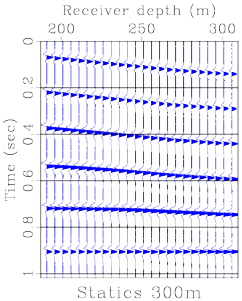


Traveltime corrections

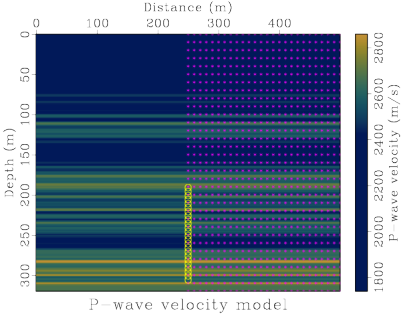


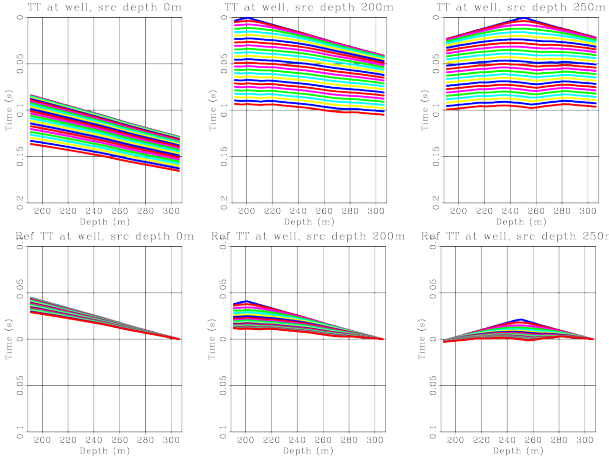






Source scanning traveltimes





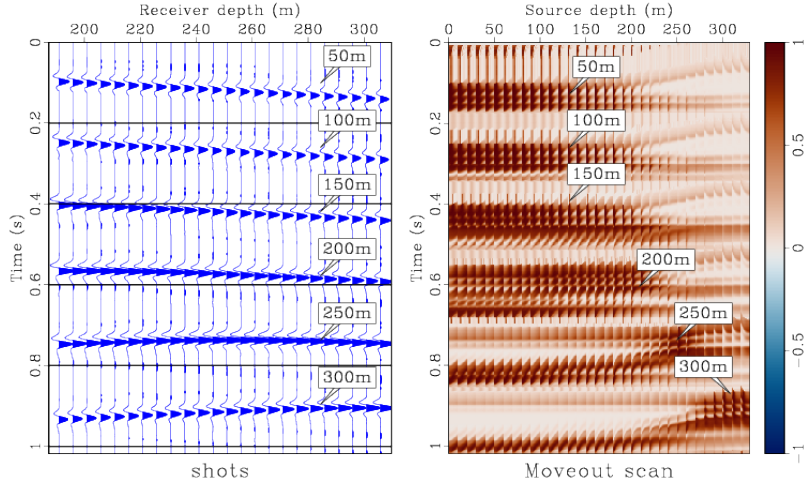
Multitrace similarity measure: Semblance

- Semblance is the ratio of the energy of a stack of N traces to N times the sum of of the energies of the N traces, summed over some interval:

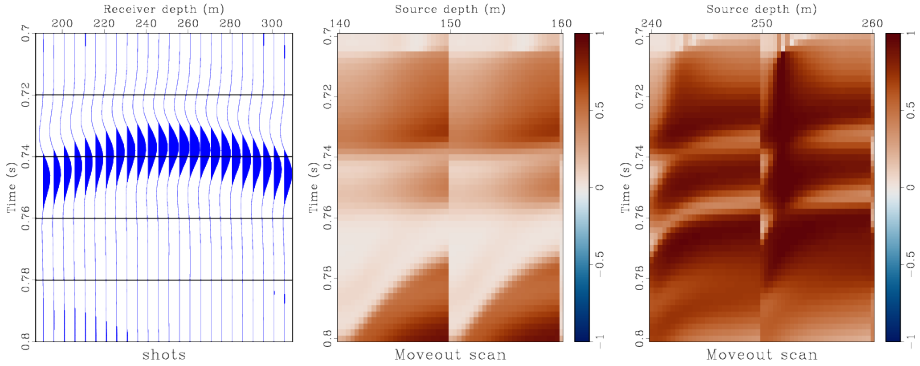
$$S_T(t) \stackrel{\text{def}}{=} \frac{\sum_{\tau=t-m\Delta}^{t+m\Delta} \left(\sum_{i=1}^{N} g_{\tau,i} \right)^2}{N \sum_{\tau=t-m\Delta}^{t+m\Delta} \sum_{i=1}^{N} (g_{\tau,i})^2}, \tag{1}$$

- It is between 0 and 1.
- When the traces are equal and not zero it is 1.

Semblance plot



Semblance plot zooming



Multitrace similarity measure: N-th root stack

- First stack the signed n-th root of the traces:

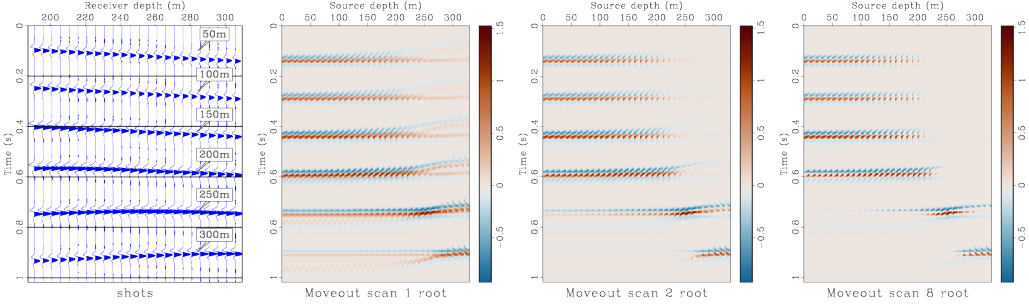
$$r'_n(t) = \frac{1}{N}\sum_{i=1}^{N} |g_{t,i}|^{1/n} sign(g_{t,i}) \quad (2)$$

- Then raise the stack to the n-th power preserving the original sign:

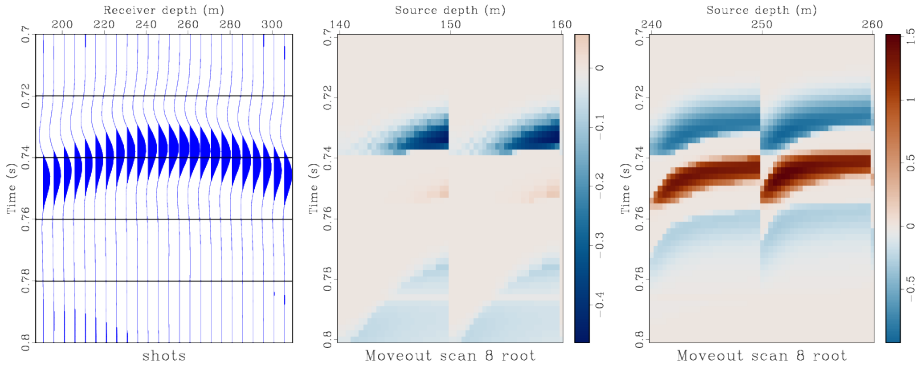
$$r_n(t) = |r'_n(t)|^n sign(r'_n(t)) \quad (3)$$

- This retains the signals in phase while reducing the random noise and signals not in phase.

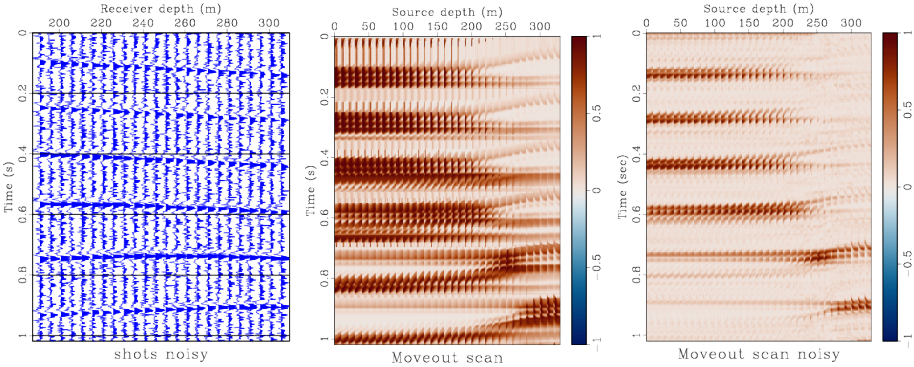
N-th root stack plot



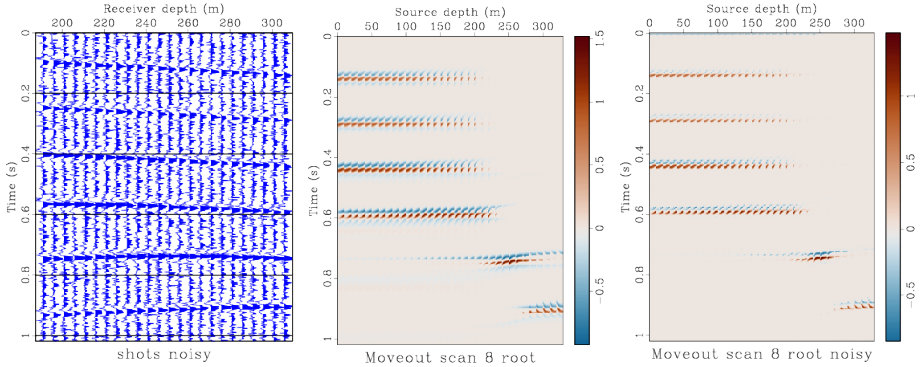
N-th root stack plot zooming



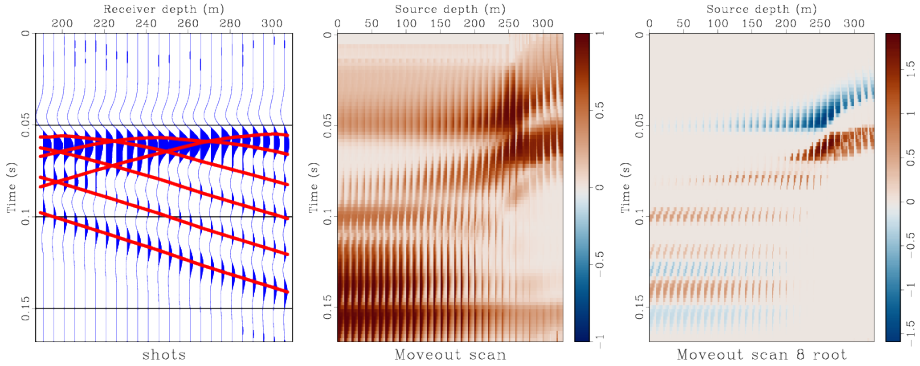
Noise effect in semblance plot



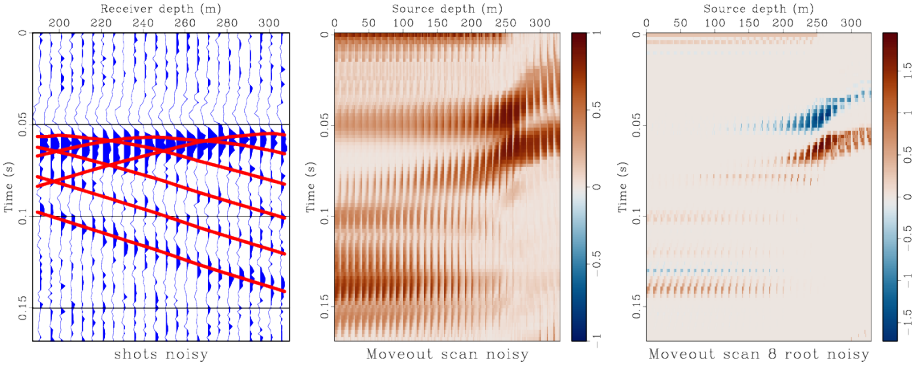
Noise effect in N-th root stack plot



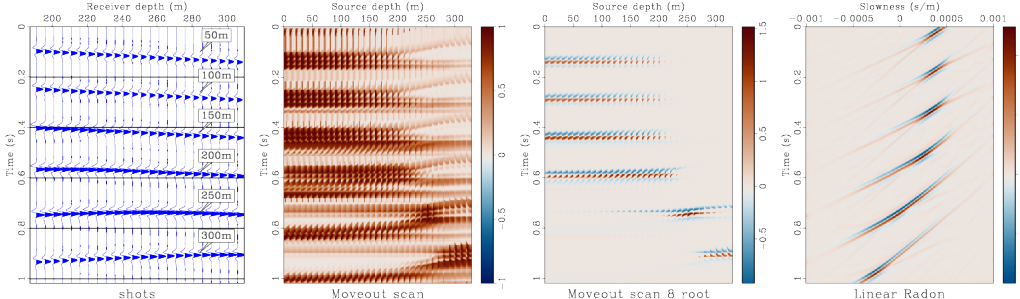
Overlapping events



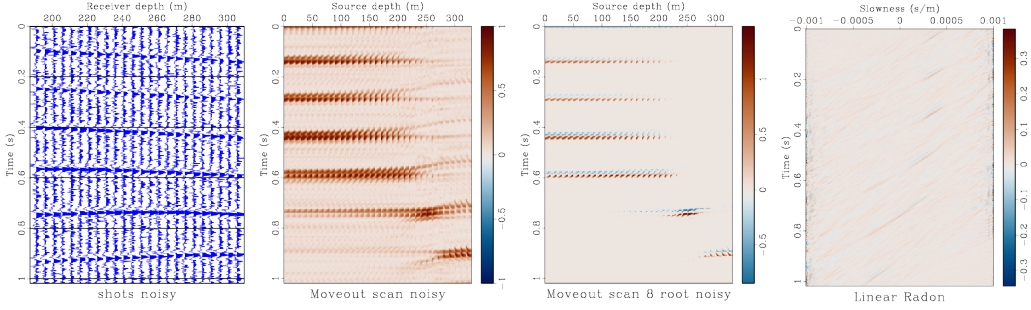
Overlapping events plus noise



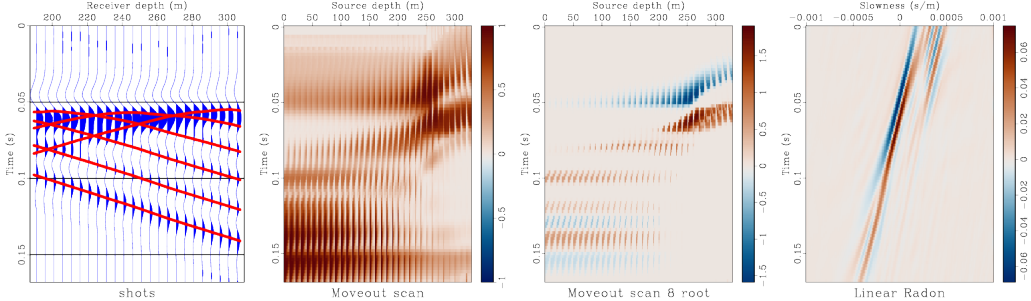
Comparison with linear Radon Transform



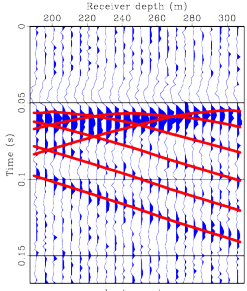
Comparison with linear Radon Transform: Noise



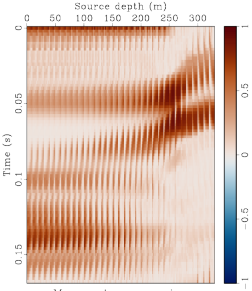
Comparison with linear Radon Transform: Overlapping events



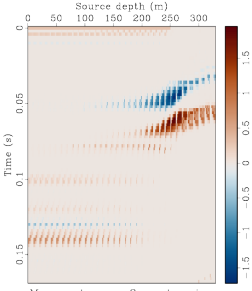
Comparison with linear Radon Transform: Overlapping events + noise



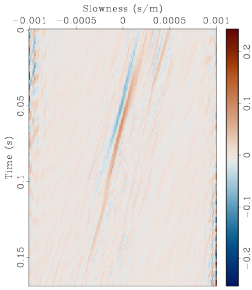
shots noisy



Moveout scan noisy

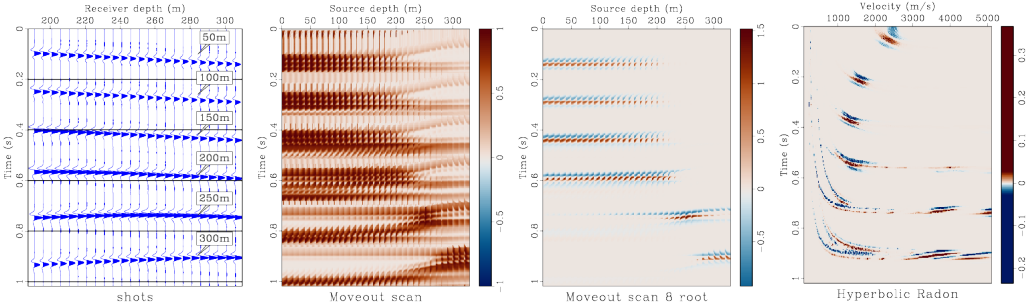


Moveout scan 8 root noisy

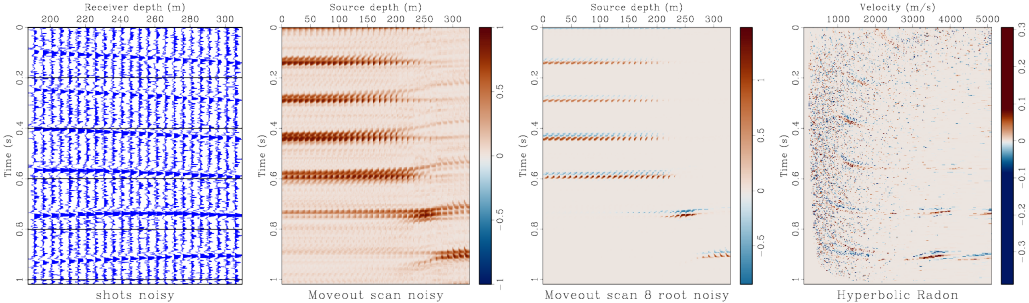


Linear Radon

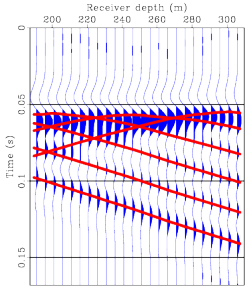
Comparison with hyperbolic Radon Transform



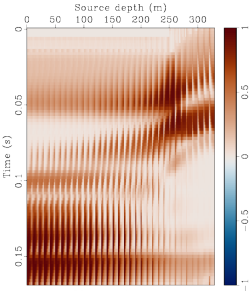
Comparison with hyperbolic Radon Transform: Noise



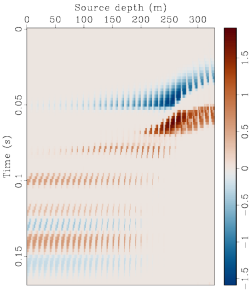
Comparison with hyperbolic Radon Transform: Overlapping events



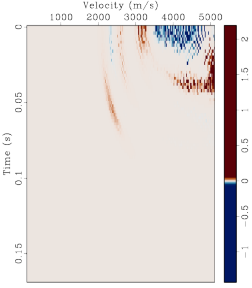
shots



Moveout scan

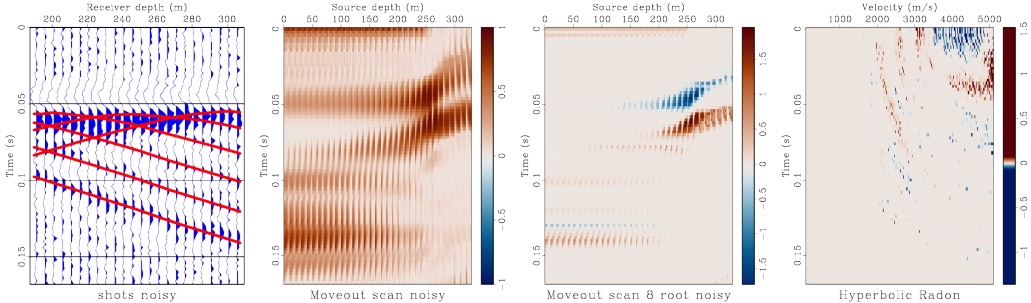


Moveout scan & root



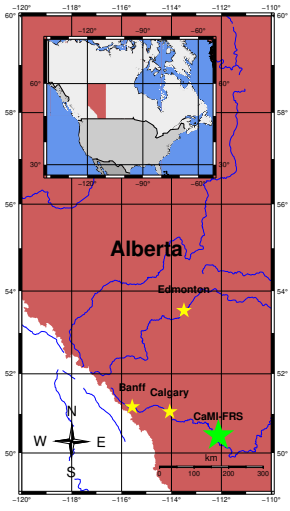
Hyperbolic Radon

Comparison with hyperbolic Radon Transform: Overlapping events + noise

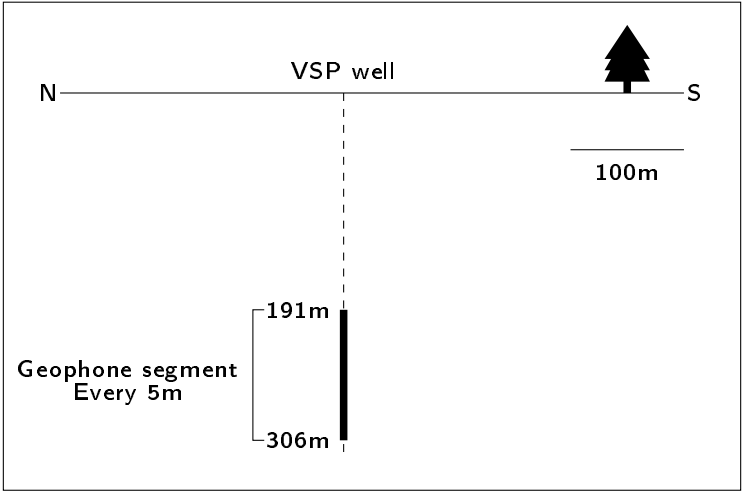


Field data

Containment and Monitoring Institute Field Research Station (CaMI-FRS)

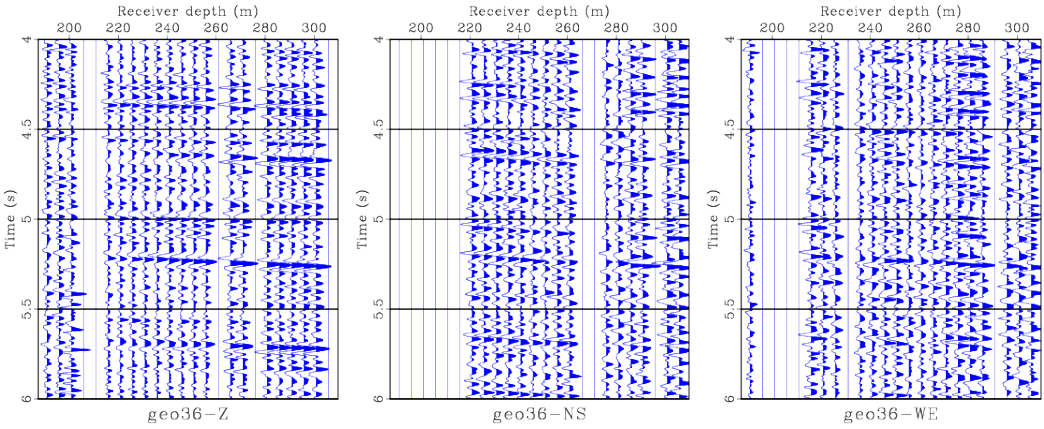


Containment and Monitoring Institute Field Research Station (CaMI-FRS)



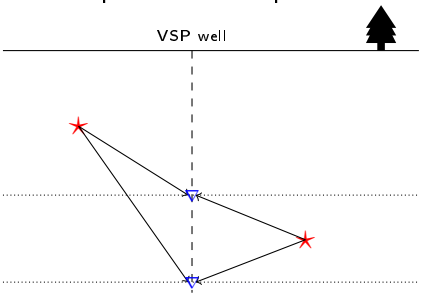
Surface operations

Surface operations VSP record

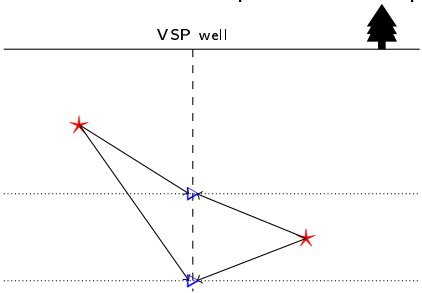


Field trace flip

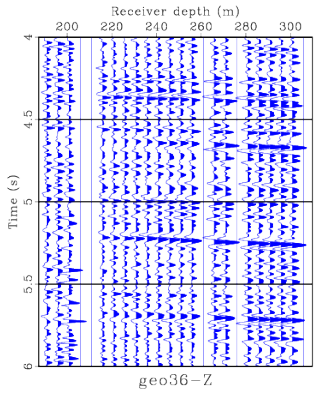
Trace flip at source depth:

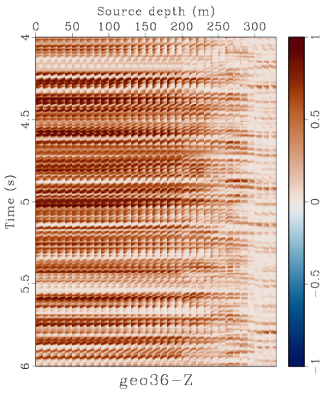


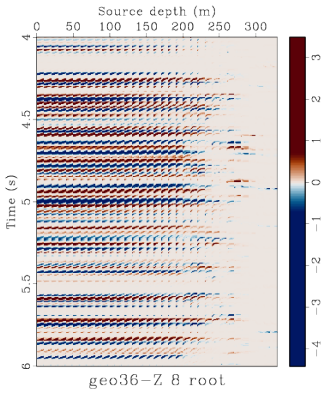
No need of trace flip at source depth:



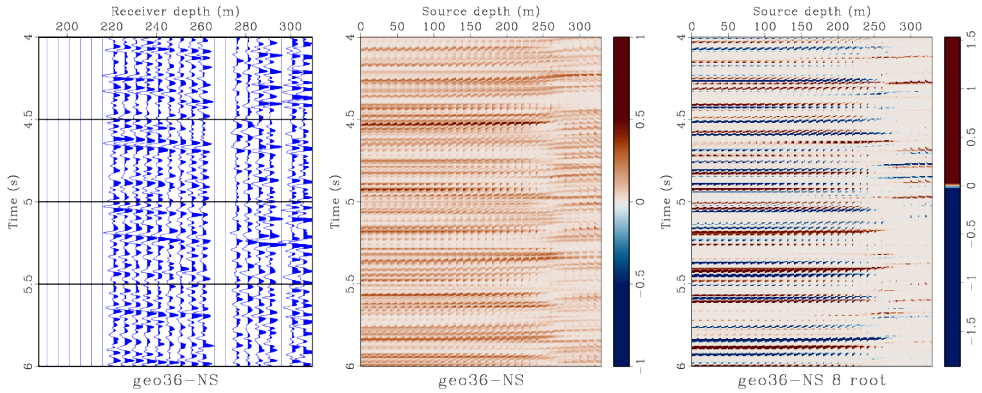
Surface operations VSP record vertical component



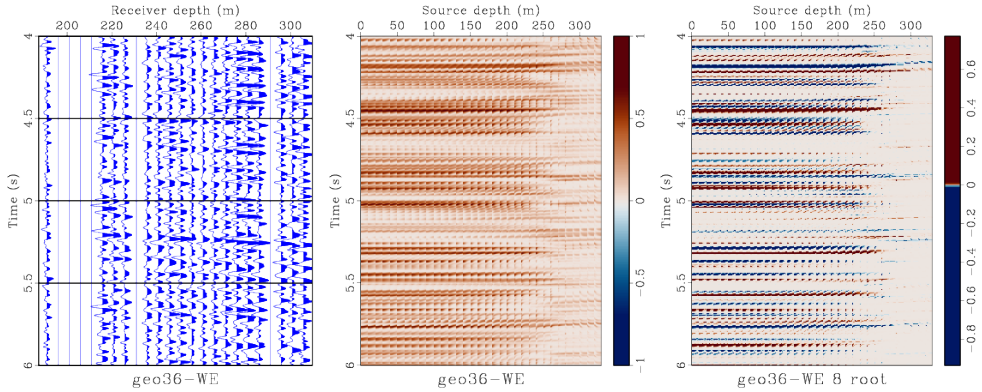




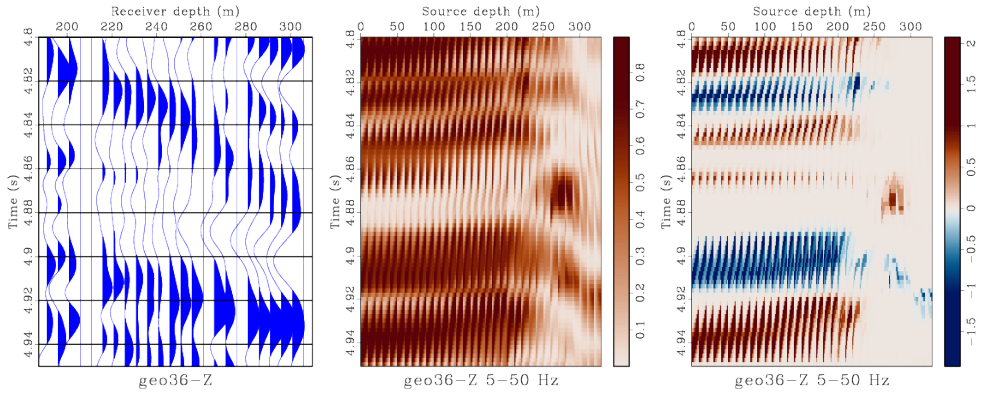
Surface operations VSP record NS component



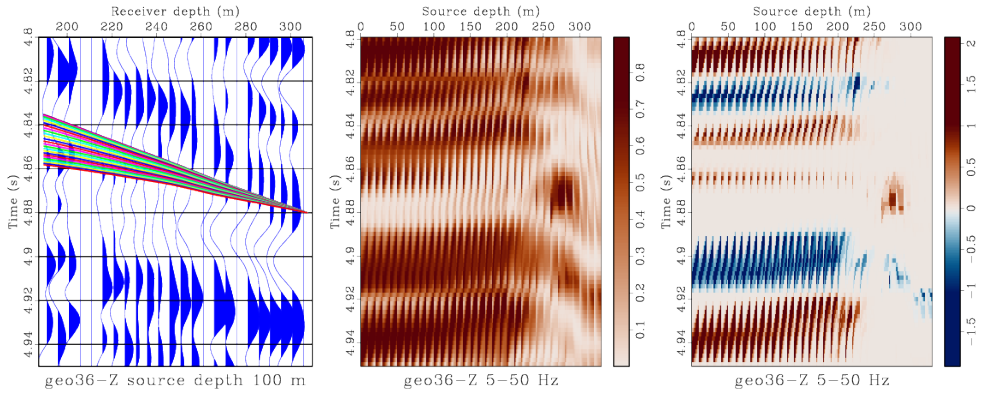
Surface operations VSP record WE component



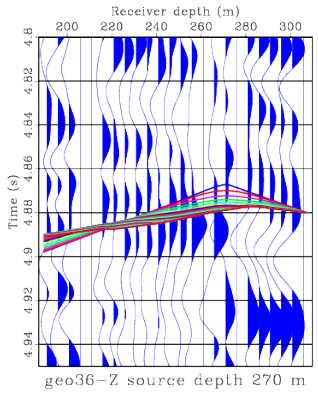
Possible anomaly



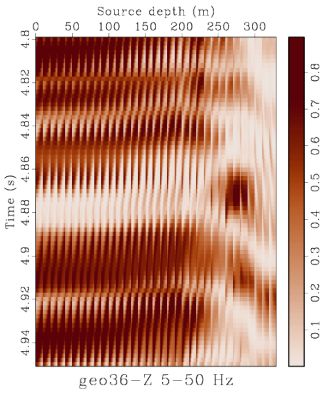
Possible anomaly. 100m source moveout



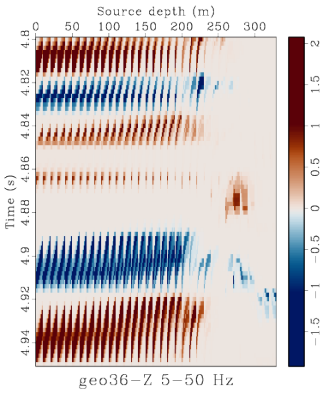
Possible anomaly. 270m source moveout



geo36−Z source depth 270 m

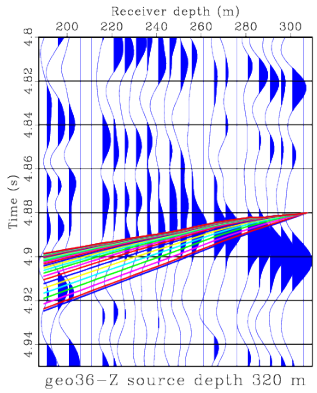


geo36−Z 5−50 Hz

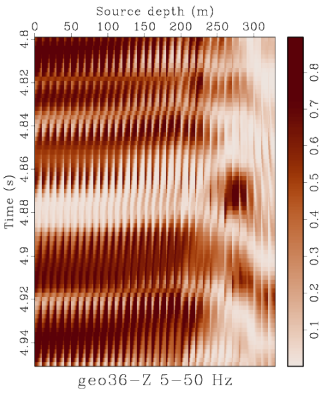


geo36−Z 5−50 Hz

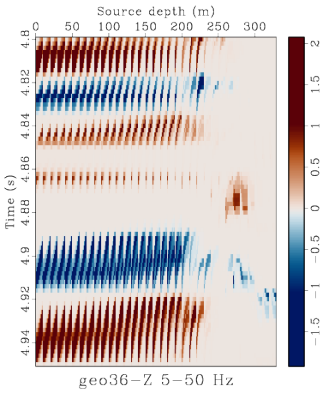
Possible anomaly. 320m source moveout



geo36−Z source depth 320 m



geo36−Z 5−50 Hz



geo36−Z 5−50 Hz

Summary

Summary

- In the synthetic data, the diffraction scanning technique was more robust to noise and overlapping events than the linear and hyperbolic Radon transforms.
- The diffraction scanning technique using the N-th root stacking produced less artifacts than one using the semblance.
- The diffraction scanning technique was able to assign an origin above the geophone array for the linear events in the field data, probably caused by surface operations and not related to the formation where the CO_2 is being injected.
- Different surface generated events can be aligned by the traveltime corrections and cause a false anomaly in the deeper part of the geophone array.

Acknowledgements

- CREWES Sponsors.
- University of Calgary Global Research Initiative.
- The Canada First Research Excellence Fund.
- The Containment and Monitoring Institute.
- CREWES students, faculty and staff.